WEB-BASED AUTOMATED REPORTING: SAVING TIME, MONEY, AND TREES

Jeffrey A. Fox*
Pacific Northwest National Laboratory
901 D Street, SW, Suite 900
Washington, DC 20024
jeff.fox@pnl.gov

Cindy Starr, Paul Baker, Kai-Dee Chu
Global Science and Technology, Inc.
6411 Ivy Lane Suite 300
Greenbelt, Maryland 20770
pbaker@gst.com
chu@gst.com
starr@gst.com

Julie Breed
NASA/Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771
julie.breed@gsfc.nasa.gov

Mick Baitinger
8403 Colesville Road, Suite 915
Silver Spring, Maryland 20910
NEXGEN Solutions, Inc.
mbating@ngsinc.com

Abstract

In the current "smaller, faster, cheaper" world of space programs, there is increased pressure to dramatically reduce costs. This has led to the design of smaller spacecraft and to a reduction in mission personnel. One of the major obstacles in reducing staff in all phases of a mission is the significant amount of paperwork that the staff must complete. For example, during routine operations, the Spacecraft Control Team (SCT) may need to complete a variety of reports including anomaly reports, pass summaries, and weekly summary reports. Boxes of these reports are archived indefinitely. The Spacecraft Emergency Response System (SERS) is an innovative Web-based suite of tools created to support "lights-out" operations. SERS automates many of the reporting activities required during both operations and integration and test (I&T). Currently, SERS is being used by several Small Explorer (SMEX) missions. In addition, SERS will be used by the Hubble Space Telescope (HST), and missions from Middle Explorers (MIDEX) and the New Millennium Program (NMP).

Key words: Lights-out operations, Automation, SERS, Anomaly management.

Introduction

At NASA's Goddard Space Flight Center (GSFC) and at space centers elsewhere, the trend is to reduce mission operations costs through automation, as demonstrated by a number of papers presented at the 1998 SpaceOps Conference.[1-10] Some organizations are even moving to lights-out operations for unmanned spacecraft,[11-14] where many of the standard operational activities are automated. In this operational setting, the spacecraft control team (SCT) no longer continuously occupies the mission operations center (MOC). The goal of lights-out operations is to reduce the overall cost of spacecraft operations by reducing the total number of hours that personnel are directly involved in day-to-day

*Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle under Contract DE-AC06-76RLO 1830.

activities. Instead, a reduced number of team members work a standard shift (perhaps 9-5, Monday through Friday) performing those tasks that cannot be automated in a cost-effective fashion. The rest of the time, the SCT acts as on-call team members who respond to notifications of anomalous conditions.

The effectiveness of this approach depends on a number of factors, including:

- How well anomalous conditions can be identified
- How much of the former in-MOC activities can be automated, and
- How well the alert system works.

NASA/GSFC's Advanced Architectures and Autonomy Branch (Code 588) is working to build technologies to help facilitate the transition to lights-out operations. One such effort is a research project called the Virtual Mission Operations Center (VMOC). The goal of the VMOC project is to work closely with operations staff to develop new technologies and workgroup computing concepts to more effectively meet the new objectives for mission operations. The VMOC project is exploring the feasibility and effectiveness of technologies such as computer-supported collaborative work (groupware), wireless communications devices, and distributed operations in order to meet these goals.

One result of the VMOC effort is the development of the Spacecraft Emergency Response System (SERS). SERS is a Web-based suite of tools created to monitor and summarize spacecraft operations and notify the SCT when anomalous conditions arise. During operations, SERS provides autonomous logging of events that require human attention (as defined by the SCT). SERS also automatically generates summaries of each pass. In addition, SERS supports automatic schedule changes and the manual reporting of anomalies. Upon logging anomalies, SERS' software agents perform customizable workflow processes that automatically generate reports and alert the appropriate SCT member(s) and/or engineer(s). This paper provides more detail on SERS' reporting capabilities.

Automation During Operations

While SERS supports anomaly logging and tracking during I&T, its capabilities are best utilized during the operational phase of a spacecraft. During routine operations, SERS receives e-mail notifications from expert systems and automatically examines ground system log files for anomalous conditions. When such a condition is detected, SERS creates an Event Report to document the condition(s) and automatically notifies the appropriate on-call team members. SERS also autonomously generates Pass Summary Reports that summarize the contents of each ground system log file that it examines. In addition, SERS handles schedule changes submitted by the Deep Space Network (DSN).

Many ground systems generate log files for each contact between the ground station and a spacecraft. These contacts occur throughout the day; so in lights-out operations, many of these contacts are performed autonomously. The log file that is generated contains documentation on the status of the spacecraft and its subsystems (i.e., health and safety data), along with any commands or procedures initiated by the SCT. SERS examines these log files with two different processes (1) to determine if a condition has arisen that requires the SCT to be notified and (2) to summarize notable messages and errors that were detected during the pass. These two processes are independently configured and executed, so that changes in the configuration of one will not affect the processing of the other.

Event Reports & Notifications

In SERS, an "event" is defined as a condition that merits the attention of the SCT and that may require some human intervention. When a new event occurs, SERS determines whom to notify based upon the event's characteristics, user-defined filters, an on-line schedule, and profiles of the SCT. SERS then mediates the response to the alert by notifying back-up personnel if the initial individuals notified of the problem do not respond to the alert. SERS uses a variety of mechanisms (pagers, e-mail, Web, and telephone) to communicate with the SCT. More detailed accounts of how SERS performs these functions are described in Fox, et. al. [13] and Baker, et al.[14] A high-level diagram of the process is shown in Figure 1.

Events in SERS are generated in two ways: (1) by receipt of a formatted e-mail message sent from an expert system or another outside process and (2) by the SERS Regular Event Processor (REP). In both cases, SERS receives the details of the event in a formatted e-mail message and autonomously generates a Pass Event Report, which is available immediately via the Web. By providing Web access, SERS allows the SCT to view reports from any computer that has a Web browser. A typical Pass Event Report is shown in Figure 2. SCT personnel who are notified of the problem can access the Web page to obtain complete information about the event.

If the spacecraft's front-end is an expert system, like Altairis,[15] the expert system sends SERS an e-mail

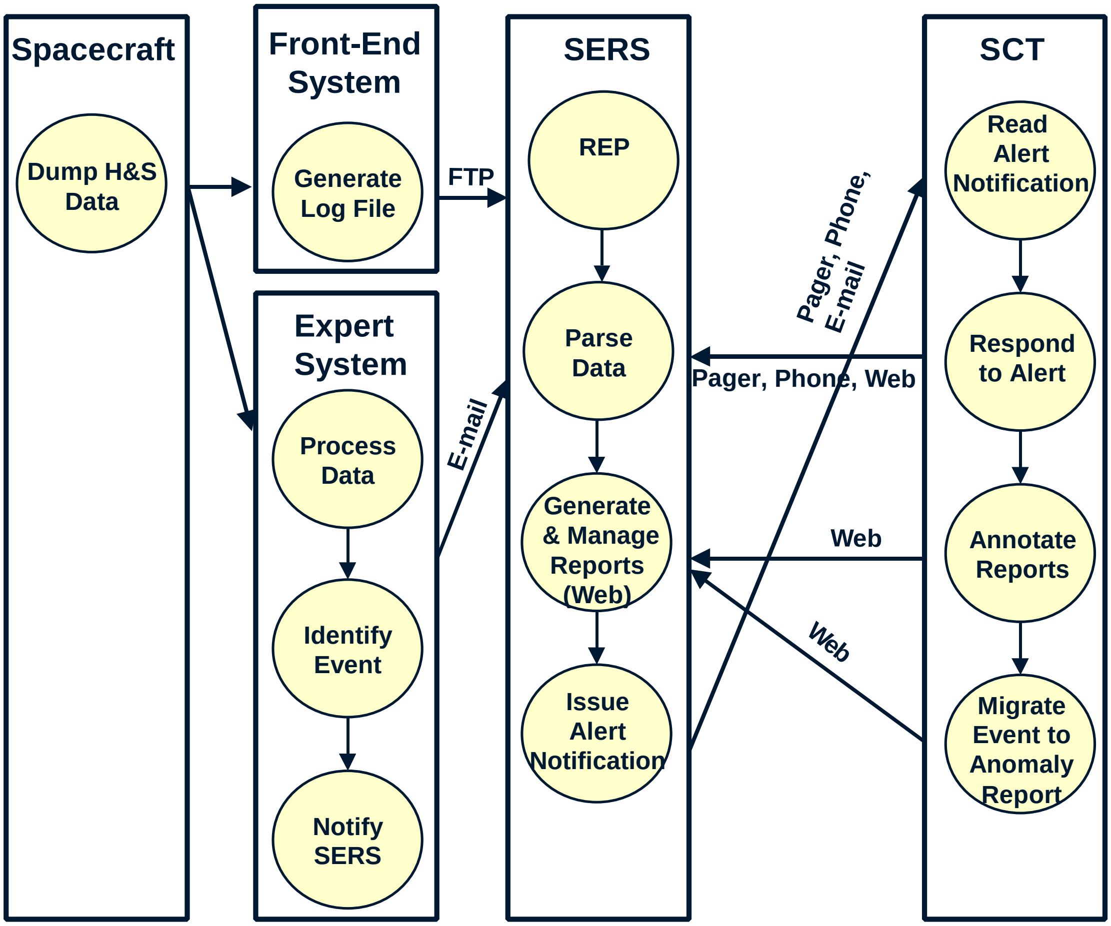


Figure 1: SERS-Mediated Workflow for Operational Event Handling

message depicting the state of the spacecraft when it determines that an anomalous condition has arisen. In addition, other external processes can automatically e-mail SERS when problems are detected. These currently include weather alerts, along with various processes that monitor the status of the other system hardware and software. Each alert causes a Pass Event Report to be generated and designated SCT personnel to be notified.

If a mission is not using an expert system as part of its front-end, the SERS REP parses the log files from ground systems, like ITOS[16] and ASIST,[17] to determine if they contain any conditions requiring SCT notification. The SCT defines the items of interest over the Web by completing forms that define the elements of interest in the log file. These are known as filters. The SCT then defines the criteria for those filters that will either trigger an alert, provide contextual information, or inhibit an alert notification.

When SERS finds the filter criteria in a log file, it automatically generates a Pass Event Report that includes information about the identified problem and any pre-selected contextual data. Alternatively, inhibit filters can be defined to prevent unnecessary alert notifications from being sent. Inhibit filters are generally narrowly defined to match certain recurring messages that may contain data that are not nominal, but are nonetheless not of interest to the SCT. This reduces the number of unnecessary notifications to a minimum.

Pass Summaries

SERS generates Pass Summary Reports based on data from two sources: (1) the Deep Space Network (DSN) schedule and (2) the ground system log file. SERS first uses DSN's 7-day pass plan, or schedule, to automatically generate skeleton reports containing schedule data for each pass for the spacecraft it monitors. A typical DSN Schedule for SMEX missions is shown in Figure 3. As the schedule is revised throughout the week, these skeletal Pass Summary

PASS EVENT REPORT #18491

ID:	PASS_INCIDENT	**Originator:**	ITOS
Mission:	TRACE	**Spacecraft:**	TRACE
Episode Started:	1/6/99 17:25:46	**Episode Ended:**	1/6/99 18:05:14
Posted At:	01/06/99 06:11:13 PM		

Background Information

Incident Started:	1/6/99 17:40:24	**Incident Ended:**	1/6/99 17:48:45
Alert ID:	NEWBASIC		
Person(s) Responsible:	John Nagy		

Ground Systems Configuration

Anomalous Alert Information

Limit Violations

Mnemonic	Value	Status	Type	Time
PSXPNDXMTCUR	1.248590927	high	Red	99-006-17:48:45

Spacecraft Events

Flight Status Message	Time
UNDEFIN Subsys-EE Code#3276 Data - (C060, EBFF, 07D5, 07D6) 98-351-12:29:44.90737 7ff9	99-006-17:40:24

Ground System Information

Ground System Message	Type	Time

Configuration

Configuration Message	Time

Other Alerts

Other Alert Message	Type	Time

Related Anomaly Reports:
Create Linked Ground Anomaly Report
Create Linked Spacecraft Anomaly Report

Supporting Web Pages: http://smexvmoc1.nascom.nasa.gov/vmoc_html/EVT_99-006-2249.orb4149.htm
Event List File: http://smexvmoc1.nascom.nasa.gov/TRACE/EVT_99-006-2249.orb4149.TXT

Figure 2: Typical SERS Pass Event Report

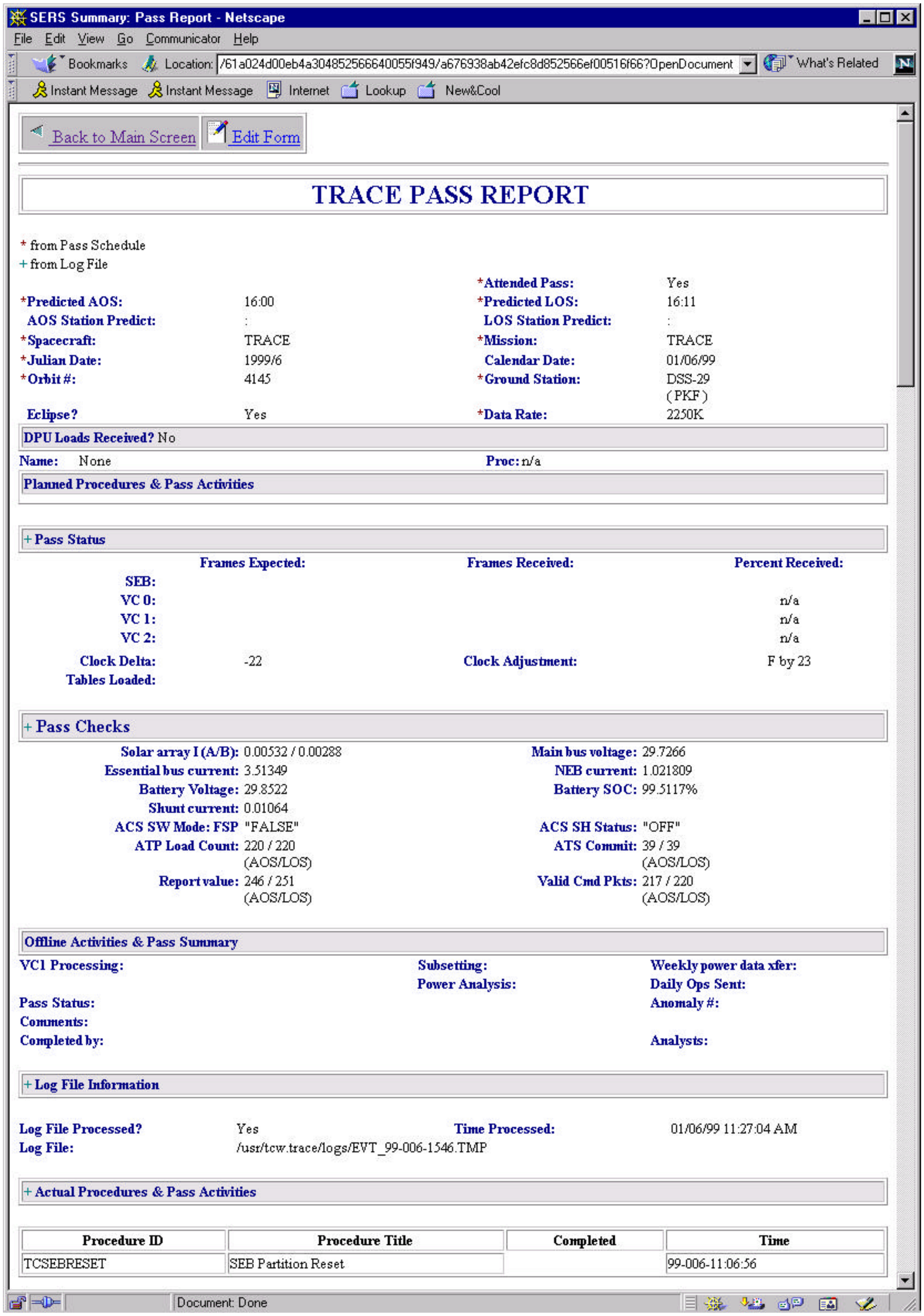
```
*                     WPS 7-DAY OPERATIONS SCHEDULE          VERSION 07 SCHE
*                           CHANGE LOG
*                  WEEK NO. 41 *** 08 Oct 98 - 11 Oct 98
*--------------------------------------------------------------------------------
*DAY START BOT EOT  END   FACILITY USER  ACTIVITY          PASS  CONFIG/ WRK
*                                                          NO.   SOE     CAT
*--------------------------------------------------------------------------------
*----------
*THU 08 Oct
*----------
*----------
*FRI 09 Oct
*----------
*----------
*SAT 10 Oct
*----------
D283 1054 1124 1140 1205  DSS-76   FAST   RTD, 2250K, 2W    8444  xxxxxx- xxx

I283 1110 1140 1210 1245  DSS-29   FAST   RTD, 2250K, 2W    8444  xxxxxx- xxx

I283 1249 1319 1339 1404  DSS-76   FAST   RTD, 2250K, EE    8445  xxxxxx- xxx


*                     WPS 7-DAY OPERATIONS SCHEDULE          VERSION 07 SCHE
*                           ACTIVITIES LISTING
*                  WEEK NO. 41 *** 08 Oct 98 - 11 Oct 98
*--------------------------------------------------------------------------------
*DAY START BOT EOT  END   FACILITY USER  ACTIVITY          PASS  CONFIG/ WRK
*                                                          NO.   SOE     CAT
*--------------------------------------------------------------------------------
*----------
*THU 08 Oct
*----------
 280 2304 2334 0004 0029  DSS-29   FAST   RTD, 2250K, 2W    8417  xxxxxx- KEY

 281 0120 0140 0149 0151  DSS-82   SAM    RTD, 900K, 2W, N  4093  xxxxxx- xxx

 281 0139 0209 0221 0246  DSS-29   FAST   RTD, 2250K, 2W    8418  xxxxxx- xxx

 281 0320 0340 0351 0421  DSS-29   TRAC   RTD, 2250K, 2W    2803  xxxxxx- xxx

 281 0412 0442 0502 0527  DSS-76   FAST   RTD, 2250K, 2W    8419  xxxxxx- xxx

 281 0604 0634 0704 0729  DSS-29   FAST   RTD, 2250K, 2W    8420  xxxxxx- xxx
```

Figure 3: Typical DSN Schedule for SMEX Missions

Reports are deleted, created, or modified to reflect changes in the schedule. Next, SERS generates a temporary report for each ground system log file once the REP has completed its examination of the file. Information that is determined to be relevant by the SCT is extracted from the log file and stored in a temporary summary. The temporary summary is then matched to the previously generated Pass Summary Report based on date, time, spacecraft, and orbit number. Relevant log file information from the temporary summary is posted automatically into the Pass Summary Report and the temporary summary is subsequently deleted. A typical Pass Summary Report is shown in Figure 4.

At certain times, matches cannot be automatically determined between the temporary reports and the Pass Summaries generated by the schedule. For example, passes may be taken that are not on the schedule. In this case, the SCT may manually generate an "Unscheduled Acquisition." This report functions in the same way as a Pass Summary Report generated from a schedule. Log file information will automatically propagate the form provided the time/date and orbit number match.

Another case is when the information in the log file may not match the Pass Summary Report that was generated from the schedule. This may be due to a data entry error during the pass or a time shift from the original schedule. When this occurs, unmatched log information is posted to the Web. When the unmatched fields are corrected by the SCT, the unmatched log data will post automatically to the correct Pass Summary Report.



SERS Summary: Pass Report - Netscape

File Edit View Go Communicator Help

Bookmarks Location: /61a024d00eb4a304852566640055f949/a676938ab42efc8d852566ef00516f66?OpenDocument What's Related

Instant Message Instant Message Internet Lookup New&Cool

Back to Main Screen | Edit Form

TRACE PASS REPORT

* from Pass Schedule
\+ from Log File

		***Attended Pass:**	Yes
***Predicted AOS:**	16:00	***Predicted LOS:**	16:11
AOS Station Predict:	:	**LOS Station Predict:**	:
***Spacecraft:**	TRACE	***Mission:**	TRACE
***Julian Date:**	1999/6	**Calendar Date:**	01/06/99
***Orbit #:**	4145	***Ground Station:**	DSS-29 (PKF)
Eclipse?	Yes	***Data Rate:**	2250K

DPU Loads Received? No

Name: None **Proc:** n/a

Planned Procedures & Pass Activities

+ Pass Status

	Frames Expected:	Frames Received:	Percent Received:
SEB:			
VC 0:			n/a
VC 1:			n/a
VC 2:			n/a
Clock Delta:	-22	**Clock Adjustment:**	F by 23
Tables Loaded:			

+ Pass Checks

Solar array I (A/B):	0.00532 / 0.00288	**Main bus voltage:**	29.7266
Essential bus current:	3.51349	**NEB current:**	1.021809
Battery Voltage:	29.8522	**Battery SOC:**	99.5117%
Shunt current:	0.01064		
ACS SW Mode: FSP	"FALSE"	**ACS SH Status:**	"OFF"
ATP Load Count:	220 / 220 (AOS/LOS)	**ATS Commit:**	39 / 39 (AOS/LOS)
Report value:	246 / 251 (AOS/LOS)	**Valid Cmd Pkts:**	217 / 220 (AOS/LOS)

Offline Activities & Pass Summary

VC1 Processing: **Subsetting:** **Weekly power data xfer:**
Power Analysis: **Daily Ops Sent:**
Pass Status: **Anomaly #:**
Comments:
Completed by: **Analysts:**

+ Log File Information

Log File Processed? Yes **Time Processed:** 01/06/99 11:27:04 AM
Log File: /usr/tcw.trace/logs/EVT_99-006-1546.TMP

+ Actual Procedures & Pass Activities

Procedure ID	Procedure Title	Completed	Time
TCSEBRESET	SEB Partition Reset		99-006-11:06:56

Document: Done

Figure 4: Typical SERS Pass Summary Report (Top Portion)

Schedule Changes

SERS also handles schedule changes from the DSN. As shown in Figure 5, a person from the DSN can notify SERS of a slip or cancellation of a spacecraft contact via the Web or by calling into SERS with a phone. When using a phone, the user is guided through a series of menus to select (1) the appropriate spacecraft, (2) the contact that must be modified, and (3) the type of modification (e.g., slip or cancel). All menu selections are made via the keypad. Users can enter comments about the modification by speaking into the phone. SERS records the voice as an attachment to the report. SERS then automatically generates a Schedule Modification Report and notifies the appropriate SCT member(s). In the future, SERS will allow on-call SCT members to accept or reject schedule changes via 2-way pager. SERS will then pass the information about the changes on to the front-end expert system so that it may make the appropriate modifications to handle the pass. Similarly, DSN personnel can send more general communications alerts to the SCT via SERS.

VMOC Vision

VMOC's ultimate goal is to provide a suite of integrated collaboration tools to support the design and documentation of the entire life cycle of a spacecraft. In the VMOC program, new longer-range technologies and concepts are being explored. One such concept is an expert system that analyzes the health and safety, or state data, of a spacecraft, as recorded in SERS Pass Event Reports. The system then automatically generates hypertext (Web) links from the SERS report to the appropriate on-line support information. A first step in this process will be to provide tools that increase SERS' utility in diagnosing and resolving anomalies.

For example, if SERS logs limit violations in the attitude control system (ACS) of a spacecraft, the expert system would automatically insert links (as part of the Web report) to schematics of the ACS, documentation on the operation of ACS, descriptions of the out-of-range mnemonics, other anomaly reports similar to that one, and other diagnostic tools.

Conclusion

Moving to a lights-out approach to operations requires the automation of many tasks. SERS is a system designed to facilitate this new paradigm. SERS provides tools to automate report generation for events, passes, and contact schedule changes. It also manages the alert notification and response process for anomalous events. In addition to the capabilities described in this paper, new features are being investigated as part of the VMOC effort and will be integrated into SERS, as they become available.

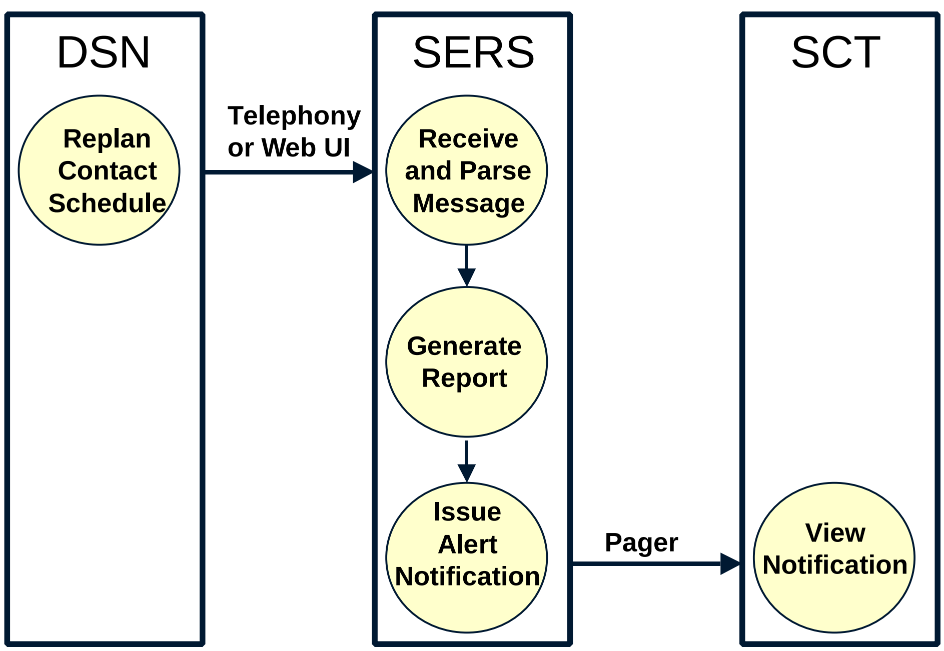


Figure 5: SERS-Mediated DSN Notification

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